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Structural change in the world economy: implications for energy use and air emissions

Report of the Secretary-General

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I. INTRODUCTION

1. In its resolution 43/194 of 20 December 1988, the General Assembly requested the Secretary-General to prepare a comprehensive report, in time for the middle of the fourth United Nations development decade, on the basis of the updated overall socio-economic perspective of the world economy, selecting for topic-oriented studies the areas of common concern which warranted the special attention of the international community. In response to this mandate and to the growing international concern with the prospects for global warming and other environmental effects of economic growth and energy use, the Department of Economic and Social Development has prepared the present report as a "topic-oriented study" on selected aspects of long-term structural change in the world economy, energy use and consequent emissions of carbon dioxide, sulphur dioxide and nitrogen oxides, to assist the General Assembly in its deliberations on long-term sustainable economic development, in the context of both the International Development Strategy for the Fourth United Nations Development Decade (Assembly resolution 45/199 of 21 December 1990, annex) and the United Nations system's follow-up to the United Nations Conference on Environment and Development, which was held at Rio de Janeiro from 3 to 14 June 1992.

2. Projections of production and air emissions to the year 2020, under different scenarios for economic growth, make particular reference to the energy-intensive economic sectors. Future changes in the world economy are determined by the projected trends in the level and composition of investment, foreign trade and consumption, and by the assumed interregional patterns of moderate technology diffusion. These trends in turn determine different rates of growth of economic activities, and thus of energy and materials requirements and levels of air emissions via the inter-industry relationships among and within regions. 1/ The projected increases in air emissions diverge greatly from their historical trends after 2000, especially in relation to GDP in the high growth scenario set out below, as current wasteful practices are reduced to some extent. The projections of energy use and air emissions do not assume the achievement of any major technological breakthroughs, but a widening application of existing efficient technologies is incorporated in the projections.

II. MACROECONOMIC TRENDS

3. The pace and distribution of world economic growth strongly influence the trends in structural change, energy use and air pollution. As compared to previous decades, world economic growth may continue to slow down in the future (see table 1). If that is the case, little improvement in average living standards and environmental conditions can be expected, and the marked disparities among countries would become even greater.

Table 1. Growth of the world economy: historical and projected under alternative scenarios for 1991-2020 a/

	1961-1973	1974-1982	1983-1990	Low growth 1991-2000	Low growth 2001-2020	Baseline 1991-2000	Baseline 2001-2020	High growth 1991-2000	High growth 2001-2020
A. GDP per economically active person (percentage)									
World b/	3.5	0.7	1.5	0.7	0.2	1.3	1.1	1.6	1.8
Developed market economies	3.6	0.9	2.5	1.3	0.8	1.9	1.5	2.6	2.6
Economies in transition	5.6	2.8	1.5	-0.1	1.5	0.9	2.0	0.9	2.6
China and Asian former centrally planned economies	4.7	3.6	6.6	3.9	3.4	4.3	3.9	4.8	4.5
Newly industrializing economies c/	3.9	2.1	2.0	1.8	0.5	2.4	1.2	3.3	2.3
Other developing countries, of which:	2.5	0.6	-0.2	1.2	1.1	1.6	1.8	1.7	2.3
Least developed countries	0.7	0.5	0.1	0.9	0.9	1.1	1.4	1.4	1.8
B. GDP (percentage)									
World	5.40	2.70	3.40	2.3	1.5	2.9	2.4	3.2	3.1
Developed market economies	4.95	2.15	3.40	1.9	1.0	2.5	1.7	3.1	2.8
Economies in transition	6.50	3.75	2.00	0.4	1.9	1.5	2.5	1.5	3.0
China and Asian former centrally planned economies	7.15	6.30	8.70	5.0	3.8	5.5	4.4	6.0	5.0
Newly industrializing economies c/	6.65	4.70	4.50	4.0	2.7	4.5	3.5	5.5	4.5
Other developing countries, of which:	2.60	2.75	2.15	3.8	3.4	4.0	4.1	4.2	4.6
Least developed countries	2.60	2.70	2.45	3.5	3.6	3.7	4.1	4.0	4.5

(Footnotes on following page)

(Footnotes to table 1)

Source: Development Policy and Analysis Division of the Department of Economic and Social Development of the United Nations Secretariat.

a/ The future productivity growth rates in the scenarios have been projected separately for each country on the basis of the country's historical experience and then aggregated into appropriate regional totals. Some countries have had a fall in their productivity in the recent past. In these cases, an assumption of a minimal rate of increase in GDP per economically active person was substituted for the historical experience. In this table, GDP is measured in constant 1980 prices and at 1980 exchange rates.

b/ The growth rate of average productivity for the world as a whole is less than for most of the major regions because the labour force is growing much more rapidly in the developing countries than in the developed countries.

c/ Argentina, Brazil, Chile, Hong Kong, Indonesia, Malaysia, Mexico, Republic of Korea, Singapore, Thailand, Taiwan (Province of China) and Venezuela.

4. The low growth scenario projects the world economy under the assumption that a long-term slow-down in the world will occur; the growth rate would be only 1.5 per cent a year after 2000. It indicates the likely long-term consequences of the economic disruptions, financial malaise and resource misallocations in the economically more advanced countries and of the high external and domestic debt, halting growth and payments disequilibria in many developing countries during the last two decades. For countries in transition to a more market-oriented economy, the scenario assumes that problems encountered in this transition will persist, and that the attempt to attain greater efficiency in production will take longer and be less successful than was generally expected.

5. The baseline scenario assumes that factors determining growth and resource use in the world economy changed fundamentally after the mid-1970s and that the changes in circumstances and trends that have prevailed since then will continue into the next century largely unchanged. The scenario extrapolates national and international policies and economic relations since 1973, except as modified by present investment rates and adjusted to reduce some extreme, highly unlikely trends. It is assumed that the developed market economies will follow the broad path laid down since 1973, but without the deep recessions that characterized the mid-1970s and early 1980s. In the developing countries, the slow growth and financial crises of the 1980s were difficult adjustments to a fundamentally new trend; structural rigidities, low commodity prices, external financing constraints and low savings associated with fiscal deficits will continue to limit the economic growth of Latin America and Africa. For the economies in transition, a prolonged period of adjustment will be required; their growth will remain slower than in the previous decades, but will rise steadily after 2000. 2/

6. The high growth scenario is based on adjustments at the national level to prevent imbalances and remove bottlenecks and on optimistic assumptions regarding international economic cooperation. The parameters determining productivity growth in each country are none the less rooted in its historical experience or that of similar countries. The scenario assumes more rapid structural transformations than the other two scenarios, and beneficial changes in present resource-use patterns and environmental conditions as new policy measures are introduced. In contrast to the alternative scenarios presented in the Secretary-General's recent long-term perspective report, 3/ in which the impacts of individual policy measures were assessed, the high growth scenario assumes that an integrated package of policies would address the main problems now constraining growth in the world economy and lead to a more stable international economic environment.

7. Under the low growth scenario, consistent with the declining and unstable pace of growth in the past, the world's productivity growth would be almost negligible, at 0.2 per cent per year, after 2000. 4/ In the developed market economies, productivity growth would slow down considerably, to 1.3 per cent annually in the 1990s and 0.8 per cent annually after 2000. With slow growth and low investment, the current high rates of unemployment would be unlikely to be reduced, political pressures against competitive imports would be high

and efforts to improve the environment would be inhibited. Technological transformation would be slow, and there would be greatly increased use of areas with fragile ecosystems, especially in subsistence economies, but also in more advanced economies with large communities at the edge of survival. The modest growth rates projected for the more manufacturing-oriented developing economies and China might allow some improvement in economic and social conditions, but would likely be associated with deterioration in the physical environment. In other groups of developing countries, persistent slow growth would preclude economic and social progress altogether, and many developing countries would also have great difficulty in employing their rapidly expanding labour force. For the economies in transition, slow improvement in their productivity growth would mean continued use of out-of-date technologies and further deterioration of the environment.

8. In the baseline scenario, a major reason for the resumption of moderate growth is the assumed return to average investment standards and productivity growth recorded in 1974-1990. In the developing countries, this would require large increases in investment as a share of GDP and in investment efficiency. Even these improvements would not generate much productivity growth in the more primary-product-oriented developing countries. In many developing countries, faster growth of GDP than in the historical reference period would be more a result of the faster projected growth in the labour force than of productivity growth.

9. Even in the high growth scenario, the projected rates of productivity growth are not as high as those attained in the 1960s. In the developed market economies, they are only 0.7 percentage point higher than in the baseline scenario in the 1990s, and 1.1 percentage point higher after 2000. The acceleration is less marked in the economies in transition. An acceleration in productivity in the developing regions follows from the scenario's assumption that the 1990s will be a period of adjustment and implementation of reforms directed at promoting more balanced economic growth in these countries. As a result of these reforms and a favourable international economic environment, productivity growth would exceed 2 per cent annually in most developing countries and 4 per cent in China after 2000. This would gradually lessen the contrasts between the developing and the industrialized countries in their levels of technical development and their competitiveness on world markets for processed materials and manufactured goods. For the least developed countries, achieving a marked increase over past performance would require successful implementation of domestic policies designed to alter present patterns of resource use and would depend upon supportive international measures.

10. Under the low growth scenario, the declining share of investment after 1990 would be accompanied by low investment efficiency, reflecting difficulties in dealing with problems of structural adjustment. Investment outlays per worker would fall in the 1990s in many of the developing countries, and would increase only slowly after 2000. The gaps among regions in investment per worker would remain large.

11. Modest rates of investment are expected under the baseline scenario. Annual investment outlays per worker in the developing countries as a whole would more than double from 1990 to 2020, but would still be less than one eighth of the 2020 level in the developed market economies. In most developing regions they would remain far below the investment outlays per worker attained in the developed market economies in 1960. Investment outlays for the majority of the labour force in the developing countries in 2020 would be less than $1,000 per worker, compared with about $11,000 in the developed market economies.

12. The increase in capital stock per worker would be much higher in all regions under the high growth scenario. After the year 2000, in response to a more favourable climate for capital formation, the investment share in GDP and outlays per worker generally would exceed their long-term historical averages. The significantly higher rate of capital accumulation in both developed and developing countries would allow for greater investment in new products and industries, making the cost of pollution abatement less of a burden.

III. STRUCTURAL CHANGE IN THE WORLD ECONOMY

13. Under the low growth scenario, structural change would be slow since lower rates of income growth inhibit investments and consumer demand for durable goods and new products. As a result, rates of growth of manufacturing are projected to be low in most developing countries, despite a recovery of their consumer goods industries in response to growing per capita income. Structural change also would be slow in the developed market economies. Service activities would continue to rise faster than goods production, but the contrast between their relative rates of expansion would lessen over time.

14. Under the high growth scenario, all lines of economic activity are stimulated both by strong domestic demand and an expansive external environment. Manufacturing in the developed market economies would expand vigorously in the 1990s in response to a growing demand for capital goods. However, after the year 2000, services and only a few industries would be the main contributors to economic growth in those countries. An acceleration in economic growth in the developing countries would be concentrated in manufacturing. As in the case of the economically more advanced countries, the initial stimulus of higher investment and income per capita would be greatest in the capital-goods sectors. Over the longer term, however, in a climate of rapid world growth the developing countries would also benefit from their strong market positions in consumer products and their growing experience in the production of capital goods. Markedly faster rates of growth of manufacturing are projected for the newly industrializing economies and China.

15. Manufacturing in the developing world 5/ is projected to quadruple from 1990 to 2020 under the high growth scenario. Transportation and communication services will expand in line with the infrastructure supporting rapid economic growth in those countries under that scenario. This would likely lead to fast growth of demand for energy and energy-intensive materials like steel and cement (see table 2). The output of the energy- and material-intensive industries, such as metals and chemicals, would increase at annual rates 1 to 3 per cent higher than those of textiles and the apparel industry in that scenario. In these projections, past relationships between the sectoral rates of growth would be likely to change in many regions.

16. Under the high growth scenario, global demand for cereals is projected to more than double, from less than 2 billion metric tons in 1990 to over 4.2 billion tons in 2020. If the current patterns of world trade in grain continue, the developed regions would need to increase grain output by less than half, while the developing world, to avoid greatly increased dependence on net imports, would have to almost triple its output, from 1.01 billion metric tons in 1990 to over 2.8 billion tons by 2020.

17. Given the limited opportunity and high costs of expanding the area of arable land in most developing countries, obtaining such increases in grain output and comparable increases in other crops would require expansion of irrigation where feasible and greatly increased use of fertilizer. 6/ The priority for increasing national and international investment in agricultural research and enhancing local training and extension services must be paramount, if world food production is to keep up with the growing demand projected under the high growth scenario.

18. While the growth of manufacturing in many developing countries has emphasized natural-resource-intensive activities, it relies increasingly on the use of technology from the economically more advanced countries. Steel-producing plants in many developing countries were built in the 1970s and 1980s, and they employ efficient technologies similar to those in the developed market economies. The share of electric arc technology in steel production is 34 per cent in the developing economies, compared with 32 per cent in the developed market economies, and about two thirds of the developing countries had phased out the open hearth process by 1990. 7/ The energy-efficient direct-reduction process for iron making has been successfully adopted in Indonesia, Malaysia, Mexico and Venezuela. In contrast, in Eastern Europe and the former USSR, the open hearth process was still used to produce 47 per cent of the steel output in 1990.

19. The use of continuous casting, which reduces energy consumption by 10 to 30 per cent in steel making, had increased from 4 per cent of world steel production in 1970 to 60 per cent in 1990. In 1990, continuous casting was used for 85 per cent of steel produced in the developed market economies and 63 per cent in the developing market economies, but only 19 per cent in Eastern Europe and the former USSR and 22 per cent in China. In the Republic of Korea and Taiwan (Province of China), its use is at 96 per cent.

Table 2. Historical and projected growth of total manufacturing and selected branches, by region a/

Region	Period	Primary metals	Non-metal minerals	Chemicals	Wood and paper products	Machine building	Total manufacturing
Developed market economies	1961-1970	5.8	5.3	8.3	4.9	6.2	5.6
	1971-1980	0.8	2.3	3.4	1.9	3.3	2.7
	1981-1990	0.6	1.0	2.8	2.2	7.3	2.6
Low growth scenario	1991-2000	0.2	1.1	2.9	2.0	2.1	2.1
	2001-2020	-0.2	0.6	2.2	1.2	1.5	1.4
High growth scenario	1991-2000	1.6	2.9	4.0	3.2	3.7	3.4
	2001-2020	1.6	2.7	3.7	2.9	3.2	3.1
Economies in transition	1961-1970	7.0	8.5	13.6	5.4	11.3	8.5
	1971-1980	3.5	4.5	8.1	4.1	9.9	5.9
	1981-1990	1.7	2.2	3.8	3.0	5.2	3.0
Low growth scenario	1991-2000	-2.5	-0.9	2.7	0.1	1.3	0.9
	2001-2020	-1.0	0.8	2.4	2.1	2.1	1.9
High growth scenario	1991-2000	-0.7	0.9	3.6	0.7	2.8	2.1
	2001-2020	0.2	2.4	3.4	3.1	3.4	3.1
China and Asian former centrally planned economies	1981-1985	6.7	12.4	10.4	8.8	14.8	10.8
	1986-1989	11.3	13.4	14.0	9.2	14.8	11.3
Low growth scenario	1991-2000	2.7	4.0	7.1	6.7	6.1	5.9
	2001-2020	0.3	2.7	4.5	5.8	3.6	3.8
High growth scenario	1991-2000	3.8	5.2	8.1	7.8	7.1	6.9
	2001-2020	2.0	4.3	5.7	5.9	5.3	5.2
Newly industrializing economies	1961-1970	10.2	9.3	9.4	5.4	11.0	7.4
	1971-1980	8.1	8.5	8.1	5.6	9.8	7.2
	1981-1990	5.7	2.8	6.8	3.0	6.2	4.4
Low growth scenario	1991-2000	1.3	3.7	5.4	5.3	4.5	4.3
	2001-2020	0.6	1.9	3.1	3.0	3.0	2.8
High growth scenario	1991-2000	3.0	5.7	6.5	5.9	6.2	6.1
	2001-2020	2.4	4.3	4.8	4.9	4.7	4.4

Table 2 (continued)

Region	Period	Primary metals	Non-metal minerals	Chemicals	Wood and paper products	Machine building	Total manu-facturing
Other developing countries	1961-1970	4.1	7.0	9.8	7.1	8.2	6.6
	1971-1980	3.2	6.6	5.3	5.4	7.1	5.4
	1981-1990	3.6	3.1	3.4	2.5	5.8	3.0
Low growth scenario	1991-2000	3.2	4.5	7.3	5.2	5.5	5.3
	2001-2020	1.5	3.1	3.6	3.8	3.9	3.6
High growth scenario	1991-2000	4.3	5.8	7.8	5.6	6.5	6.0
	2001-2020	2.5	4.5	4.6	4.9	4.9	4.7

Source: Development Policy and Analysis Division of the Department of Economic and Social Development of the United Nations Secretariat.

a/ Average annual rate of growth of manufacturing, value added, in 1980 United States dollars and at 1980 exchange rates.

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20. In all of the major economic sectors, most of the world's output is still produced in the economically more advanced countries. However, the strong complementarity between production of raw materials in the developing countries and manufacturing in the developed countries has weakened in recent decades, establishing the preconditions for a new world division of labour. The developing world has greatly increased its share of world production of several of the most energy-intensive products. By 1988 it had almost half of the world's production of cement compared with less than one fifth in 1960, and similar changes occurred in other materials. The share of the developing world in global aluminium output tripled to 15 per cent and its share of pig iron production more than doubled, to 24 per cent. The six largest producers in the developing world accounted for about 19 per cent of world steel output in 1990. 8/ Aluminium production in the developing world was negligible in 1960, compared with its two-thirds share of world mining of bauxite; but it had 16 per cent of the world's aluminium production by 1990. 9/

21. The projected shifts in the locations of industrial production are consistent with the likely macroeconomic trends. The share of the newly industrializing economies and China in world manufacturing will continue to increase under the high growth scenario. The projected increases in production of energy-intensive products in the developing world would imply a rising total use of energy. These countries also would generate a rapidly increasing share of the world's air pollutants unless the adoption of energy- and materials-efficient technologies accelerates.

IV. CHANGES IN ENERGY USE

22. Many technological advances have been made in energy exploration and in the production, transportation and use of energy resources since 1960. Energy conservation and efficiency measures were particularly successful in the developed market economies, facilitated by fast structural changes and some shifts of energy-intensive industries to the developing countries. But similar measures were not widely applied in either the developing countries or Eastern Europe and the former Soviet Union, and the energy price declines in the mid-1980s led to resumed growth in energy consumption in many market economies.

23. World consumption of commercial energy exceeded 7.5 billion metric tons of oil equivalent in 1988, or two and one half times the level recorded for 1960. The share of the developing countries in world energy consumption increased from 14 to 23 per cent during the same period, but over half still takes place in the developed market economies. The disparity in per capita consumption of commercial energy between the economically advanced countries and the developing world remains enormous; in 1988, the average level in the developing countries was hardly 10 per cent of the average in industrial countries and in sub-Saharan Africa it was merely 1 per cent of that in North America.

24. Traditional fuels, such as fuelwood, charcoal, bagasse and animal wastes, including the non-commercial portion, are still major energy sources in developing countries; their share in world consumption is approximately 13 to 14 per cent. 10/ Such fuels account for more than 60 per cent of the total energy consumption in sub-Saharan Africa, and approximately 30 per cent in South and South-East Asia and Latin America. These fuels are predominantly used for households, but they provide 28 per cent of industrial energy use in sub-Saharan Africa.

25. Many energy-efficient practices and technologies do not involve complex procedures and are already on the market, providing considerable scope for improvement in energy efficiency world wide. Most industrial processes still consume much more energy than is necessary: basic operations such as the production of ethylene from ethane or the separation of oxygen from air, in most countries, use between four and six times the theoretical minimum thermodynamic requirement. In some cases, technological breakthroughs such as the basic oxygen conversion and electric arc processes for steel making already have drastically improved energy efficiency. 11/

26. Although projected reductions in energy use for the individual processes do not look dramatic by themselves, a chain of improvements in various processes and sectors accumulated over time can yield substantial energy savings. In the developed market economies and the economies in transition, the average energy requirement per unit of output will be 24 per cent less in 2020 than in 1990 for metals, rubber and chemical products, 44 per cent less for cement and 38 per cent less in the pulp and paper industry. Under the high growth scenario, new industrial capacity is also expected to be more

energy efficient in the developing countries. In these countries it is assumed that housekeeping measures, such as the improvement of heat insulation, combustion controls and optimal operation schedules, will be adopted in existing industrial processes by the year 2000. Further retrofitting of existing capacity for the recovery of waste heat and the replacement of inefficient boilers are expected to take place later. All of these measures together would reduce energy requirements by one third per unit of most energy-intensive products, and by 40 per cent in the case of cement between 1990 and 2020.

27. Fuel use for transport and electricity generation is rising rapidly in all regions. The transport sector consumed almost one quarter of the world's final energy consumption in 1988, and over half of the energy liquids. Prospects for further energy saving in the transport sector appear to be more modest than those in industry. The average fuel efficiency of automobiles (measured as kilometres driven per litre of gasoline) has already increased by 30 per cent since 1970. 12/ But most of the automobile manufacturers have already drawn heavily upon existing technology, making further energy saving for gasoline-fuelled vehicles difficult. None the less, the next 30 years will be long enough for new technical breakthroughs - for example, engines that can operate with leaner mixtures of fuel and air, and ceramic engines, which can operate at a higher temperature.

28. Road transport based on gasoline-powered motors will remain the most important mode of transportation, and its share of total oil consumption will grow. The share of road transport is increasing in China and India, where coal-fuelled railroads are now the major means of transportation. Developing countries that do not yet have extensive gasoline distribution systems may be in a better position to develop systems to provide alternative fuels. 13/ So far, there are only a few million propane-burning motor vehicles in the world, out of 420 million motor vehicles. Smaller cars also are acceptable to the public in many countries. However, even the projected 30 per cent improvement in fuel efficiency during the period 1990-2020 would not prevent an increase in total fuel demand for vehicles from the fast growth of the number and use of motor vehicles. Under the high growth scenario, demand for automobiles in the developing world would almost double every 10 years.

29. The projected economic growth in the developing world is likely to lead to large increases in household demand for commercial fuels and electricity. As per capita income increases, household demand for electricity grows rapidly. In the Asian newly industrialized economies and China, the use of refrigerators has already increased rapidly, though the use of air conditioners is not yet as widespread. The potential for saving energy in households is substantial, especially for electric appliances. It is also estimated that heat savings of up to 30 per cent are possible with little or no capital cost; comparable savings are possible for air conditioning. Considerable potential for improvement in lighting and electric appliances has already been proved. The assumptions for this sector in the high growth scenario emphasize only those best-practice technologies that are already available. 14/

30. Despite concerns about global warming, most of the developed market economies are planning to increase the share of electricity generated by fossil fuels between 1990 and 2005, mainly by increasing the share generated by natural gas. Increased shares for coal are planned in Japan, Oceania and medium-income Western Europe. In most regions, moderate substitution of natural gas for coal and oil in electricity generation will take place after 2000. In the developed market economies, the combined share of coal and oil used for electricity is expected to decline by 15 per cent from 2000 to 2020, and to be replaced by natural gas. A conservative assumption was also made in all three scenarios that the combined share of nuclear power, hydroelectricity and other non-fossil fuel sources of electric power would remain fixed until 2020 at the levels estimated for the years 2000 to 2005 for each region, except Japan and China and other Asian former centrally planned economies. 15/

31. The average efficiency of electric power generation, as measured by the ratio between the primary energy input and the electricity output, rose from 25 per cent in 1950 to 35 per cent around 1990 in fossil fuel plants world wide. The new combined-cycle gas turbine, working in sequence with the steam turbine, has an efficiency level of more than 40 per cent in modern gas-fired plants, and it may reach as high as 55 per cent in future plants. An experimental combined-cycle, coal-fired plant is expected to operate at almost 50 per cent efficiency. When electricity and hot water are produced jointly, in a so-called co-generation plant, the overall energy efficiency may reach 80 per cent. But the diffusion of these technologies remains slow. Moreover, increases in thermal efficiency are expected to be slow in the developed regions even if new technologies are commercially proved, given the long lifetime of existing power plants, the long time needed to construct new ones, and the high cost. 16/ Under the high growth scenario, the average conversion efficiency for the developed market economies will reach 37 to 38 per cent by 2000 and 41 per cent by 2020. It is assumed that conversion efficiency will increase more rapidly in the economies in transition than in the developed market economies between 1990 and 2000, and at the same rate thereafter. By 2020 the average efficiency in most of the developing regions will reach the 1990 level of the developed regions, through wider utilization of existing technology.

32. Energy losses in the production, distribution and transmission of electric power are expected to decline as electricity production and distribution grids expand at high rates in the developing world. 17/ But without some technological breakthrough, such as the commercial use of superconductors, such losses in the developed market economies will not be greatly reduced by 2020 from their recent level of 10 per cent. It is assumed that the newly industrializing economies and the economies in transition will reduce their losses from approximately 15 per cent in 1990 to 10 per cent by the year 2000, and to 9 per cent by 2020. Other developing regions are expected to reduce these losses from about 20 per cent in 1990 to 15 per cent by 2000 and to 10 per cent by 2020.

33. Differences in GDP and investment growth under the three scenarios would be likely to affect the speed of diffusion of more efficient and cleaner technologies. Under the high growth scenario these technologies assume 15 to 40 per cent savings of fossil fuels, electricity and raw materials per unit of output, depending on the particular technology or sector. As the level of investment in each region in the other two scenarios would be significantly lower than in the high growth scenario, the technology diffusion rates would probably be much lower. For example, the newly industrializing economies may achieve one third less savings due to efficiency improvements under the low growth scenario, as their investments during the period 1990 to 2020 are only two thirds of those in the high growth scenario. In the industrialized countries, technologies would depend less on the differences in investment among the scenarios. In the developed market economies, the focus of savings in energy and materials is on end uses, and low investment might even encourage more efficiency improvements. The economies in transition might become less material-intensive as enterprises respond more to consumer preferences. However, at the world level, slower growth and lower investment would imply a more energy-intensive path of economic growth.

34. In the developing world and the economies in transition, energy conservation programmes will be implemented as technical and institutional barriers soften, allowing these regions to upgrade their technological capacity and efficiency. In the high growth scenario, the first round of energy savings is considered to be virtually costless, and the upper bounds of potential gains from better "housekeeping" measures in most of these regions will be achieved by the year 2000. It is assumed that, by 2010, there will have been enough retrofitting to achieve the lower bounds of currently available long-term technical measures. By the year 2020 almost all feasible retrofitting of existing capacity is expected to occur, so that the upper bounds of efficiency from existing technologies are achieved. For the developed market economies, similar measures are expected to result in large energy savings.

35. The energy intensity of the world economy is expected to fall by almost 30 per cent from 1988 to 2020, under the high growth scenario (see table 3). All of the major regions would contribute to this decline after 2000, by far the largest decline being expected in the economies in transition. Energy intensity in most of the developing regions would peak around the year 2000, and then decline, as it responds to changes in the shares of the energy-intensive sectors in these countries. On a per capita basis the industrialized countries would still produce and consume much higher volumes of energy-intensive products than the developing world in 2020.

36. In the high growth scenario, the share of the developed market economies in world consumption of fossil fuels is projected to decline to 35 per cent by 2020, from almost 50 per cent in 1990. Natural gas use is projected to grow faster in the newly industrializing economies and China and the former Asian centrally planned economies than in the developed market economies. The share of coal will decrease in the developed market economies from 25 per cent in 1990 to 21 per cent in 2020, and in economies in transition it will decrease

Table 3. Energy intensity, a/ historical and projected under the high growth scenario, by region

Region	1960	1973	1988	2000	2020
World	0.82	0.78	0.67	0.61	0.48
Developed market economies	0.70	0.70	0.50	0.42	0.29
Economies in transition	2.01	1.79	1.48	1.30	0.54
China and Asian former centrally planned economies	2.59	1.92	1.39	1.24	1.03
Newly industrializing economies	0.44	0.52	0.54	0.55	0.49
Other developing countries	0.28	0.34	0.62	0.78	0.61

Source: Development Policy and Analysis Division of the Department of Economic and Social Development of the United Nations Secretariat.

a/ Measured in metric tons of coal equivalent per thousand United States dollars of GDP, in 1980 United States dollars and at 1980 exchange rates.

from 36 to 32 per cent. However, the shares of different fossil fuels will not change for the world as a whole.

37. Future changes in economic structure and fuel mixes will have major impacts on the regional levels of emissions. In 1990 the economies in transition consumed slightly more coal than China and the Asian former centrally planned economies. By 2020 the use of coal in this region is projected to be about 3 billion tons, under the high growth scenario, while in the economies in transition it would reach only 1.1 billion tons. These projections might be revised upward, however, if use of existing oil reserves in the former USSR turns out not to be cost-effective; coal and natural gas would then be the most feasible substitute for those reserves.

38. Total fossil fuel use in 2020 is projected to be 19.7 billion tons of coal equivalent under the high growth scenario, 16.5 billion under the baseline scenario and 13.9 billion under the low growth scenario (see table 4). Under the high growth scenario, the use of electricity continues to grow faster than the use of fossil fuels. The ratio of electricity generation to fossil fuel consumption in the newly industrializing economies is projected to be 60 per cent greater in 2020 than in 1990, and 50 per cent greater in the

Table 4. Commercial fossil fuel consumption in 1990 and 2020, under alternative scenarios for economic growth a/

(Millions of metric tons of coal equivalent)

Region	1990	Scenarios for 2020		
		Low growth	Baseline	High growth
World total	9 845	13 920	16 540	19 650
Developed market economies	4 925	4 500	5 400	6 775
Economies in transition	2 390	2 730	3 310	3 500
China and Asian former centrally planned economies	985	2 630	3 140	3 715
Newly industrializing economies	615	1 310	1 620	2 120
Other developing countries	945	2 750	3 070	3 540

Source: Development Policy and Analysis Division of the Department of Economic and Social Development of the United Nations Secretariat.

a/ The technology diffusion rates are assumed to be the same in all three scenarios.

other developing countries and China, compared to only 20 per cent in the developed market economies and the economies in transition.

39. All five major regions would use much more fossil fuel under the high growth scenario than under the low growth scenario if technology diffusion rates are the same. The relative difference would be greatest in the developed market economies and the newly industrializing economies, reflecting the effect of high per capita incomes on the demand for cars, air conditioning, heating and other energy-intensive products and services. The difference would be relatively less in the economies in transition, because of their great potential to save energy in their present, very inefficient methods of production in many sectors, even with low growth of their GDP.

V. AIR EMISSIONS OF CARBON, SULPHUR AND NITROGEN OXIDES

40. The external costs 18/ associated with energy production and use are a matter of increasing concern, especially the negative effects of pollution in the atmosphere. The current policies of the developed countries seem strong enough to curtail further the emissions of some air pollutants. These countries will continue to use desulphurization equipment on power plants, and nitrogen emissions from stationary sources will be reduced through combustion modifications. It is expected that power plants in those countries will also use catalytic reduction, such as post-combustion scrubbers, for removal of nitrogen. Emissions of nitrogen oxides from mobile sources will be further reduced through the use of catalytic converters. The developing regions, however, are not expected to invest significantly in pollution control, except that China and India are expected to increase washing of coal, which will lower its sulphur content and therefore its sulphur emissions by roughly 30 per cent.

41. The projected increases in annual consumption of fossil fuels would result in large increases of air emissions of carbon and nitrogen compounds but much smaller increases of sulphur emissions, and even decreases in several regions. Under the high growth scenario, large reductions per unit of GDP would be achieved in the developed market economies - 57 per cent for sulphur dioxide, 46 per cent for total nitrogen oxides, and 40 per cent for carbon dioxide (see table 5). For the economies in transition somewhat smaller improvements are projected except for sulfur emissions. Much smaller changes, compared with historical trends, are projected for the developing regions.

42. With regard to both sulphur dioxide and nitrogen oxide emissions, technologies exist for their eventual reduction to acceptable levels at a cost which would be accommodated with high economic growth. Carbon dioxide emissions are not amenable to a technological solution, but they could be reduced through higher energy efficiency and lower inputs of materials in many sectors, and through a better mix of fuels or greater use of the various carbon-free energy sources. If all of the efforts to improve efficiency and pollution abatement assumed under the high growth scenario were undertaken under the low growth scenario, despite the much lower level of total investment, the global emissions of carbon dioxide from fossil fuel use would increase only to 7.9 billion tons of carbon in 2020. Sulphur emissions would stabilize at less than 130 million tons under the low growth scenario, but nitrogen oxides would increase by 40 per cent, to more than 110 million tons. However, technological diffusion under the low growth scenario would almost certainly be much slower than under the high growth scenario; thus the global emissions of carbon dioxide in 2020 would probably be around 10 billion tons of carbon, which is only 10 per cent less than the level projected under the high growth scenario. Similarly, the global emissions under the economic growth rate and investment rate of the baseline scenario would probably be 10.5 to 11 billion tons.

Table 5. Emissions of carbon dioxide, sulphur dioxide and nitrogen oxides per unit of GDP: indices for 1980-2020 under the high growth scenario

(1990 = 100)

Region	1980	1990	2000	2010	2020
			Carbon dioxide		
World total	112	100	92	83	76
Developed market economies	121	100	84	70	60
Economies in transition	118	100	92	79	70
China and Asian former centrally planned economies	154	100	92	87	79
Newly industrializing economies	99	100	103	90	85
Other developing countries	67	100	118	109	99
			Sulphur dioxide		
World total	132	100	81	66	55
Developed market economies	147	100	74	55	43
Economies in transition	143	100	77	56	40
China and Asian former centrally planned economies	178	100	77	65	51
Newly industrializing economies	91	100	102	81	74
Other developing countries	68	100	118	96	81
			Nitrogen oxides		
World total	118	100	91	82	75
Developed market economies	132	100	82	67	54
Economies in transition	121	100	92	78	67
China and Asian former centrally planned economies	159	100	91	84	78
Newly industrializing economies	105	100	102	92	89
Other developing countries	68	100	106	103	98

Source: Development Policy and Analysis Division of the Department of Economic and Social Development of the United Nations Secretariat.

43. The projections assume only limited extension to other countries of regulatory measures and specific technologies used thus far to reduce air emissions in the developed market economies. If similar measures and technologies become widespread in the developing world, global sulphur dixoide and nitrogen oxide emissions might be reduced substantially below those projected in the high growth scenario. However, even in regions at a higher level of industrialization than most of the developing world, such as eastern and southern Europe, very little investment in pollution abatement has been made thus far.

Emissions of carbon dioxide

44. The projections of carbon dioxide (CO_2) emissions are determined by regional fuel demand and fuel mix. Research on the separation, fixation and final disposal of CO_2 has not been encouraging, except for some positive results in cement processing. Policies on CO_2 reduction therefore must focus on improving energy and material efficiency and substituting other energy sources that release less CO_2 than the carbon-rich fossil fuels.

45. Thermal electricity generation is the biggest single sector, accounting for 34 per cent of the world's total CO_2 emissions from the burning of fossil fuels and other production processes. Manufacturing is the second largest source, accounting for 25 per cent. Almost half of these emissions by manufacturing come from the production of iron, steel and chemicals. In industrialized countries, the production of metals, chemicals, cement, pulp and paper is responsible for three quarters of CO_2 emissions from manufacturing processes. The transport sector and households account for 29 per cent. Agriculture accounts directly for only 2 per cent.

46. Total CO_2 emissions from fossil fuels are projected to increase to 11.2 billion tons in 2020, under the high growth scenario (see table 6). Emissions of CO_2 in the developing world currently are about half the level in the developed market economies, but they are projected to be almost 50 per cent higher than in the developed market economies by 2020. Per capita CO_2 emissions will increase in all regions, but they will still be 2 to 3 times as high in the developed market economies and the economies in transition as in China and the newly industrializing economies and 8 times as high as in the other developing countries. The developed market economies would have to introduce significant additional measures, beyond the technical changes assumed in this scenario, to limit their CO_2 emissions in the year 2000 to their 1990 levels, as envisaged in the United Nations Framework Convention on Climate Change. 19/

Table 6. Air emissions in 1980, 1990 and 2020 under the alternative scenarios a/

Region	1980	1990	Scenarios for 2020		
			Low growth	Baseline	High growth
Carbon from fossil fuels (millions of metric tons)					
World total b/	4 806	5 640	7 930	9 450	11 250
Developed market economies	2 597	2 790	2 490	3 020	3 800
Economies in transition	1 207	1 320	1 480	1 795	1 900
China and Asian former centrally planned economies	486	600	1 750	2 080	2 470
Newly industrializing economies	249	340	710	875	1 150
Other developing countries	268	530	1 500	1 680	1 930
Sulphur oxides (millions of metric tons of sulphur dioxide equivalent)					
World total b/	125	127	126	152	181
Developed market economies	51	45	29	36	45
Economies in transition	49	45	29	34	37
China and Asian former centrally planned economies	14	19	33	39	46
Newly industrializing economies	5	8	14	18	23
Other developing countries	5	10	22	26	30

Table 6 (continued)

Region	1980	1990	Scenarios for 2020		
			Low growth	Baseline	High growth
Nitrogen (millions of metric tons of nitrogen dioxide equivalent)					
World total b/	69	78	112	131	154
Developed market economies	35	35	28	34	43
Economies in transition	19	21	23	27	29
China and Asian former centrally planned economies	5	8	22	26	31
Newly industrializing economies	5	6	14	17	22
Other developing countries	4	8	25	26	30

Source: Development Policy and Analysis Division of the Department of Economic and Social Development of the United Nations Secretariat.

a/ The rates of technology diffusion in the three scenarios are the same as those discussed in the text for the high growth scenario.

b/ Totals may not add up because of rounding.

Emissions of sulphur dioxide

47. Anthropogenic sulphur emissions in 1990 are estimated to be 127 million tons of sulphur dioxide (SO_2). The developed market economies account for about 35 per cent of the world's SO_2 emissions, but their share is falling as a result of stringent emission control standards. In the United States of America, SO_2 emissions fell from 14 million tons of sulphur in 1970 to 10 million tons in 1985, and in France from 1.8 million tons in 1980 to 0.7 million tons in 1988. Japan, which has very stringent emission standards, now accounts for only 0.4 million tons. The success in reducing SO_2 emissions has been due to progress in desulphurization technologies as well as the wider use of low-sulphur fuels. In Japan the average sulphur content of fuels for electricity generation was reduced from 1.7 per cent in 1969 to 0.3 per cent in 1986, mainly through the importing of cleaner oil.

48. One third of the world's SO_2 emissions from fossil fuels are discharged by the economies in transition. These emissions, per unit of fuel consumption, are 3 to 5 times greater in Eastern Europe than the average for Western Europe, and they are still rising, partly because of dependence on domestic high-sulphur fuels. These emissions are now considered to be the main cause of widespread acid rain in central Europe. Total SO_2 emissions in the developing regions, except China, are only 10 per cent of the world total, but they may be underestimated, for lack of complete data for many developing countries.

49. Since high levels of sulphur are contained in coal and heavy distillates of oil, the control of emissions at the fuel-intensive industrial and power plants that depend on these high-sulphur fuels can greatly reduce total emissions. Flue-gas and fuel desulphurization technologies are now in regular use in several economically advanced countries. There are at least 10 different desulphurization methods; each works with different types and conditions of sulphur-containing fuel or exhaust gas and produces different forms of sulphurous by-products. 20/ The cost of desulphurization equipment to meet stringent emission standards like those of Japan might be estimated at $100 billion to $150 billion for the world as a whole. 21/

50. Global SO_2 emissions from fossil fuel are projected to increase from 127 million tons in 1990 to 180 million tons in the year 2020, under the high growth scenario (see table 6). Unlike the case of CO_2, emissions of SO_2 per capita would increase only in the developing world. In the economies in transition, SO_2 emissions per capita would fall more than one fourth, but still be almost twice as high as in the developed market economies in 2020. 22/

Emissions of nitrogen oxides

51. Out of 78 million tons of nitrogen oxides (NO_x) (measured as nitrogen dioxide equivalent) released annually in the world, 70 per cent is emitted in the economically more advanced countries. Roughly half of the total NO_x emissions come from mobile sources like cars, trucks and ships. In countries where railroads are the main form of transport, as in China and India, the

emissions of NO_x are much lower in relation to GDP and total transport activity than in the developed regions.

52. To date, the control of NO_x emissions is not nearly as stringent as that of SO_2 in most countries. Despite efforts to control NO_x, these emissions have increased during the 1980s in most countries for which reliable data are available. In Japan, however, they were cut back from 1.8 million tons in 1975 to 1.2 million tons in 1986. Technologies have been available since the 1970s to reduce NO_x emissions from gasoline engines to approximately one tenth of the average emissions from conventional engines. New engines already employ catalytic converters together with various modifications of engine design to reduce these emissions, and further improvements are expected. New types of technologies for reduction of NO_x emissions from diesel engines continue to become available; new engines can reduce NO_x by 50 per cent compared to conventional ones. Another 30 per cent reduction is considered possible as these technologies are further developed.

53. The technologies to reduce NO_x emissions at electric power plants and other stationary sources are not yet well established. Among the available methods for flue-gas denitrification, the catalytic reduction process is most widely used. However, it is expensive and its average efficiency ranges only from 40 to 70 per cent. Through slight modifications of the designs of fuel nozzles, combustion chambers and other parts of a fuel burner, so-called "low-NO_x" burners can suppress NO_x formation by up to 50 per cent.

54. Annual NO_x emissions from the world's use of fossil fuels are projected to increase from 78 million tons in 1990 to 154 million tons in 2020, under the high growth scenario (see table 6). In the developed market economies, they would stabilize at about 40 million tons. Large increases would occur in the developing regions, where use of motor vehicles would grow rapidly while catalytic converters would likely remain uncommon, unless their costs were reduced significantly to make them affordable to most car-owners in those countries. Consequently, global NO_x emissions per unit of fossil fuel consumption would be about the same in 2020 as in 1990. Per capita NO_x emissions would remain high (40 to 60 kg) in the industrialized countries; in the developing world they would double but still be far below the average level in the industrialized countries in 2020. 23/

VI. CONCLUSIONS

55. The output of energy-intensive materials such as metals, chemicals, cement, fertilizers and paper typically grows rapidly during the intermediate stage of industrialization. This pattern of structural transformation is already taking place in a number of developing countries, and it is expected to continue in most of them and to spread to some others during the period 1990-2020, but under the high growth scenario the average energy intensity per unit of GDP would continue to decline in most regions. However, the projections of total energy use indicate that in the group of other developing

countries the average energy intensity would rise during the 1990s; only by 2020 would it fall back almost to its 1990 level.

56. Even with the considerable increases in the efficiency of energy use and the reductions in air emissions per unit of GDP that would be achieved under the high growth scenario, the world's annual consumption of fossil fuels would double by the year 2020. This would proportionally increase emissions of CO_2 and NO_x, while emissions of SO_2 would rise by over 40 per cent. Overall, the effects of high growth would be better than those of low growth. Total emissions of CO_2, SO_2 and NO_x would probably be only 10 per cent higher than in the low growth scenario, as the higher total investment would allow higher energy efficiency and more investment in pollution abatement. But much additional effort would be required to limit the emissions of CO_2 to their 1990 levels, as envisaged in the United Nations Framework Convention on Climate Change.

57. In order to reduce or at least limit the long-term growth of global emissions, especially of CO_2, the consideration of options needs to be extended beyond slowing the world's economic growth. Technologies already exist to reduce SO_2 and NO_x emissions substantially at costs that would be acceptable with high economic growth. The growth of CO_2 emissions could be limited through higher efficiency in the use of energy and lower inputs of materials in various production processes, and through a better mix of carbon fuels and substitution of other, carbon-free energy sources.

58. Reductions of CO_2 emissions through fuel switching would be feasible in many regions, especially those with large natural gas reserves. A massive changeover from coal and oil to natural gas, however, would require greatly expanded exploration and production, and the collaboration of the world's major coal and oil users. But these countries probably cannot afford not to use their plentiful, inexpensive coal resources unless they are enabled to import large quantities of natural gas at reasonable prices. High capital investment would be required for the development of an integrated system for world trade in natural gas, and for the development of the vast hydropower potential of the developing countries, which is estimated to equal half of the world's annual consumption of oil.

Notes

1/ These relationships are specified in the United Nations Global Input-Output Model, which has recently been updated for the United Nations by Professor Leontief's associates at New York University, with financial support from the Government of Norway. The model represents the world economy in terms of 16 regions linked by trade and capital flows. The inter-industry submodel for each region covers 44 sectors; technological alternatives for key sectors critical to the levels of air emissions, such as electric power generation, steel production and transportation are explicitly considered.

Notes (continued)

2/ The major areas presented in most of the tables in this report (developed market economies, economies in transition, China and other Asian former centrally planned economies, newly industrializing economies, and other developing countries) are used as convenient analytical groupings for presentation of the main trends in the various regions. Data for smaller regions and some individual countries are presented, mainly in the text, to illustrate the broad trends in the major regions if region-wide data is not available, or to show significant exceptions to those trends.

3/ Overall Socio-economic Perspective of the World Economy to the Year 2000 (United Nations publication, Sales No. E.90.II.C.2 and corrigendum).

4/ In the approach used to prepare the projections, the annual rate of increase in labour productivity may be traced to the ratio of investment to GDP and the degree of investment efficiency.

5/ The term "developing world" is used in this report to refer to all of the developing regions as a whole, including China and other Asian former centrally planned economies.

6/ Many areas in the developing world still use very little fertilizer; increased use could probably generate large increases in output, especially if accompanied by adequate training for farmers.

7/ The open hearth process requires about 3.7 times as much energy, per ton of steel output, as the electric arc process. The open hearth process uses 0.16 tons of coal equivalent (tce) per ton of steel, plus 0.6 tce per ton of pig iron used as input.

8/ Among these six producers, China more than doubled its production to 67 million tons in 1990, and is now the world's fourth largest producer. The Republic of Korea and Taiwan Province of China, taken together, produced more than 33 million tons in 1990, up from about 12 million tons in 1983, and India increased its output from 9 million tons to 15 million. Brazil's production increased from 15 million tons in 1980 to more than 20 million tons in 1990; according to government plans, it will reach 50 million tons by the year 2000.

9/ The newly industrializing countries in Latin America, mainly Brazil, increased their production of bauxite by only one half from 1960 to 1988, but their production of primary aluminium grew from a negligible 20,000 tons to 1.2 million tons in those 28 years.

10/ See the report of the Intergovernmental Group of Experts on New and Renewable Sources of Energy (A/AC.218/1992/9).

Notes (continued)

11/ The share of the electric arc process may reach half of world steel production in 2000, compared with 30 per cent in 1990. But new capacities in the developing world are expected to use traditional blast furnaces and the basic oxygen process, owing to a lack of metal scrap. In many developing countries charcoal is still used as a substitute for coke; this requires 80 per cent more energy than using coke. In 1986 Brazil produced 7 million tons of pig iron by using charcoal. On the other hand, developing countries rich in natural gas can use the direct-reduction process to produce iron. Venezuela is already producing 3 million tons of iron per year with this process.

12/ In 1987 the nominal fuel efficiency of the average new passenger car in the United States was 60 per cent higher than in 1976. A new passenger car emits 96 per cent less carbon monoxide and hydrocarbons and 76 per cent less nitrogen oxides than a comparable car in 1967.

13/ In Brazil, alcohol-fueled cars accounted for 96 per cent of all automobiles sold in 1985, by which time 3.7 million out of the total stock of 12.9 million motor vehicles were fueled by ethanol.

14/ All furnaces in existing dwellings in the developed regions are expected to be replaced by more efficient ones by 2020, reducing energy requirements for heating by 25 per cent, per dwelling unit, from the 1990 levels. It is also assumed that the existing housing stock will be weatherized sufficiently to reduce energy requirements for space heating by another 25 per cent per unit, and that most of the existing stock of home appliances will be replaced by 2010, and all of it by 2020. While all households cannot be expected to purchase the most energy-efficient model available in a given year, the average model purchased in 2020 is assumed to be at least as efficient as the most efficient model expected to be available in the mid-1990s.

15/ Many of the operating licences of nuclear plants in the developed regions expire around the year 2010, and renewal of their licences will meet stiff public opposition. The continued operation of most of the nuclear plants in the economies in transition is already in serious question. Japan plans to expand its nuclear generating capacity from about 25 per cent of total electricity in 1990 to 60 per cent in 2020. In China and other Asian former centrally planned economies, the combined share of hydroelectric and nuclear power may increase by 3 percentage points in 1990-2020.

16/ Electric power engineers estimate that a 1 per cent increase in energy efficiency for a new plant will raise its investment costs by about 1 per cent. Moreover, the use of energy-using pollution control devices, like scrubbers on coal plants, will tend to lessen thermal efficiency. Alternatives to the current technologies, such as fluidized-bed combustion and atmospheric and pressurized integrated combined cycle plants, are expected to be only pilot projects.

Notes (continued)

17/ Electric power losses in developing countries, even after adjustments for inadequate metering and power lost to theft, range up to 20 per cent.

18/ Financial costs and non-financial burdens imposed on someone other than the producer or user of a product.

19/ Article 4, para. 2 (b); see the report of the Intergovernmental Negotiating Committee for a Framework Convention on Climate Change on the work of the second part of its fifth session, held at New York from 30 April to 9 May 1992 (A/AC.237/18 (Part II)/Add.1).

20/ The most common flue-gas desulphurization method traps SO_2 in a gas scrubber with an alkaline solution. This desulphurization equipment typically has an efficiency of 80 to 90 per cent removal of SO_2 from the gas after combustion.

21/ Japan installed desulphurization equipment costing a total of 480 billion yen ($6.2 billion at 1988 prices) in the 1970s. Japan accounts for approximately 7 per cent of the world's consumption of oil and 3 per cent of the coal but for only 0.5 per cent of the global sulphur emissions.

22/ Most Governments in the region of the Economic Commission for Europe have signed and ratified the 1979 Convention on Long-range Transboundary Air Pollution (United Nations, Treaty Series, vol. 1302, No. 21623) and the 1985 Helsinki Protocol thereto, which called for States to reduce their SO_2 emission or its transboundary flux by 30 per cent or more. As of 1988, 12 of the parties to the Protocol reported that they had already reached the 30 per cent target ahead of schedule, and 10 parties announced that they would go on to reduce emissions by more than 50 per cent.

23/ The 1988 Sofia Protocol to the 1979 Convention on Long-range Transboundary Air Pollution calls upon the parties to reduce national annual NO_x emissions 30 per cent by 1998, compared to the level of any year between 1980 and 1986.